CHARM MIXING FROM LIFETIMES AT BABAR

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Abstract

Preliminary limits on the D^0 mixing parameter $y = \Delta\Gamma/2\Gamma$ are obtained using $57.8\,\mathrm{fb}^{-1}$ of data collected by *BaBar* in 2000-2001: $y = (1.4 \pm 1.0(\mathrm{stat.})^{+0.6}_{-0.7}(\mathrm{syst.}))\%$. Provided that CP is conserved, y is extracted by measuring separately the D^0 lifetime for the Cabibbo-suppressed decays K^-K^+, $\pi^-\pi^+$ and the Cabibbo-favored $K^-\pi^+$.

1 Introduction

The mixing parameters $x = \Delta M/\Gamma$ and y are predicted by the Standard Model (SM) to be very small in the charm sector [1]: $|x|, |y| \leq 10^{-3}$. Thus charm mixing provides a sensitive probe for physics beyond the SM at the level of the current experimental sensitivity (10^{-2}).

One possible search for mixing effects can be performed by measuring the lifetime difference between D^0 decaying, through a Cabibbo-suppressed diagram, to a CP-even eigenstate (such as K^-K^+ and $\pi^-\pi^+$) and decaying to the Cabibbo-favoured $K^-\pi^+$ final state assumed to be an equal mixture of CP-even and CP-odd eigenstates [1]. In the CP-conserving limit, y can be expressed in terms of a lifetime ratio: $y + 1 = \tau(K^-\pi^+)/\tau(h^-h^+)$ with $h^-h^+ = K^-K^+, \pi^-\pi^+$. Many systematic uncertainties in the D^0 lifetimes cancel in the ratio so that the lifetime ratio provides a particularly sensitive measurement of y.

The preliminary measurement of y presented here is based on a data sample of $57.8\,\mathrm{fb}^{-1}$ collected with the *BaBar* detector, at the PEP-II asymmetric e^+e^- collider, during the years 2000 and 2001. Detailed description of PEP-II and *BaBar* can be found elsewhere [2].

2 D^0 selection and lifetime extraction

D^0 candidates were reconstructed for the decay sequence $D^{*+} \to D^0 \pi_s^+$, $D^0 \to h^+h^-$, satisfying track and vertex quality requirements. Particle identification criteria were applied to both the tracks of the h^+h^- pair to distinguish among the three decay modes and to suppress background. The rather tight kaon selection was characterized by a pion contamination $< 3\%$ for momenta $< 3\,\mathrm{GeV/c}$. The difference between the D^* and the D^0 reconstructed mass, $\delta m = m(h^+h^-\pi_s) - m(h^+h^-)$, was also crucial for background rejection. The δm-cut around the δm distribution peak (fig. 1) depended on the quality of the π_s track.

The selection of D^* candidates coming from $c\overline{c}$ continuum was obtained by asking for a D^0 momentum $> 2.5\,\mathrm{GeV/c}$ in the e^+e^- center-of-mass frame. This constrains the D^* to decay within the interaction region (beam spot) thus allowing a π_s *refitting* that highly improves δm resolution. The final invariant mass distributions are shown in fig. 1.

The D^0 proper time is derived, in the plane transverse to the beams direction, from the flight length defined as the distance between the D^0 and D^* vertices projected on the D^0 transverse momentum.

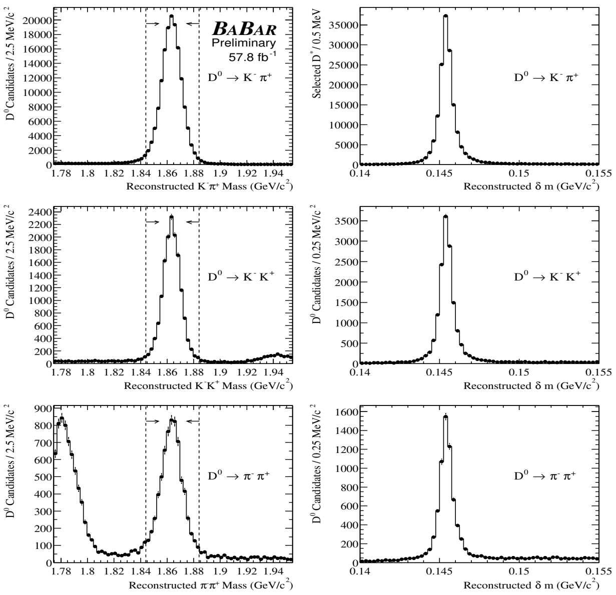

Figure 1: Left: reconstructed D^0 invariant mass distributions after the application of the selection criteria. Right: corresponding δm distributions, apart from the δm-cut, for the D^0 candidates within the mass window given by dashed lines. In this window about $158,000$ $D^0 \to K\pi$, $16,500$ $D^0 \to KK$, and $8,350$ $D^0 \to \pi\pi$ candidates were found with signal purities of about 99.5%, 97.1% and 92.4% respectively.

An unbinned maximum likelihood fit was used to extract the three lifetimes. The likelihood function is divided into three different decay time distributions, one for the signal and one for each of the background components, *flying* (charmed) and *not-flying* (light quarks). Each distribution is smeared by convolution with a proper time resolution function modelled as a sum of three gaussians, the first two having a width proportional to the event-by-event proper time error.

To combine the signal and background likelihood functions, each D^0 mass distribution was fit to derive the probability for each D^0 candidate to belong to the signal. The sidebands were included in the fit region to better constrain the background. The lifetime fit results are shown in fig. 2 superimposed on the proper time distributions.

3 Lifetime ratio systematics

Since the statistical uncertainty on the D^0 lifetime for Cabibbo-favoured sample is about 1.3 fs whereas the overall systematic uncertainty (about $3 \div 4$ fs) can be reduced with further studies, an absolute D^0 lifetime value is not presented at this stage. The fit result is fully consistent with both our previous check on a sample of $12.8\,\mathrm{fb}^{-1}$ and the PDG value, $412 \pm 2(stat.)$ fs and 412.6 ± 2.8 fs respectively [3].

However many systematic effects on lifetime cancel in the lifetime ratio and therefore in y. The systematic uncertainties in y, summarized in table 1, were estimated using large signal Geant4 simulated

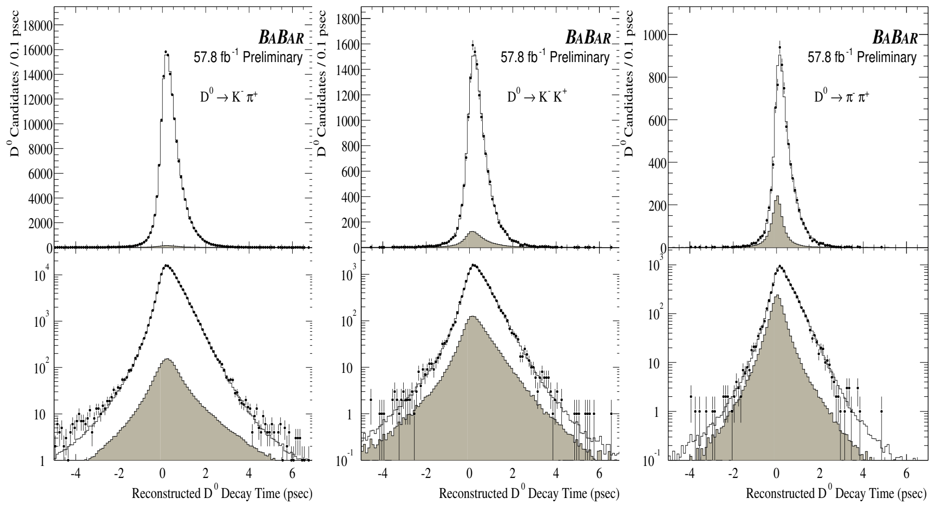

Figure 2: The white histogram represents the fit result; the grey one is the portion assigned to the background by the fit.

	y Uncertainty (%)	
Systematic Uncertainty Source	K^-K^+	$\pi^-\pi^+$
Tracking	0.2	0.9
Particle Identification	0.2	0.4
Background & D^* Fragmentation	0.2	0.6
Alignment and Vertexing	$^{+0.2}_{-0.1}$	$^{+0.3}_{-0.1}$
Monte Carlo Statistics	$^{+0.4}_{-0.6}$	$^{+0.4}_{-0.9}$
Quadrature Sum	$^{+0.6}_{-0.7}$	$^{+1.2}_{-1.4}$

Table 1: A summary of the systematic uncertainties in the y measurement.

data samples that were modified by variations in the event selection criteria and suitable variations reflecting the current understanding of the detector, the uncertainties in background level and composition, in beam spot position and size. The y estimation in simulated data shows no bias within statistical errors. The largest source of uncertainty is from Monte Carlo statistic and will be certainly reduced in the future.

4 Results and near term prospects

The y measured values for K^-K^+ and $\pi^-\pi^+$ are $(1.5 \pm 1.3^{+0.6}_{-0.7})\%$ and $(1.0 \pm 1.7^{+1.2}_{-1.4})\%$ respectively, being the first(second) error reported statistical(systematic). Their average $y = (1.4 \pm 1.0^{+0.6}_{-0.7})\%$ should be compared with the limits of similar precision provided by BELLE and FOCUS, $(-0.5 \pm 1.0^{+0.7}_{-0.8})\%$ and $(3.42 \pm 1.39 \pm 0.74)\%$ respectively [4]. The *BABAR* result is consistent with zero but suggests a positive value compatible also with the FOCUS one, and induces us to perform a new measurement over a larger data sample.

Limits on x and y derived by the time-dependent analysis of $D^0 \to K^+\pi^-$ wrong-sign decays will be soon released by *BABAR*.

References

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